In the Specification

Please amend the specification as follows:

Please change the Title of the Invention to:

Electric Motor With Electronic Brake

Paragraph 1

The invention relates to a retarded or electronically braked electric motor comprising at least one field winding and a commutating armature being connected in series with the at least one field winding and being fed during operating mode by a supply voltage, and further comprising means for switching into a braking mode.

Paragraph 3

A retarded or electronically braked electric motor as mentioned at the outset and designed as a series motor is known from WO 91/03866.

Paragraph 8

US 5,828,194 to Canova discloses a control circuit of a DC series motor comprising two half bridges each with a respective switch with controlled opening and closing. The first half bridge connects a pole of the field winding to the battery and the second of the half bridge connects a pole of the armature to the battery. The control circuit is designed to feed power resulting from the braking operation back into the battery. To this end the armature must be pole reversed which is ~~effected~~ affected by contactors for reversing. However, the utilization of mechanical contactors for switching between an operating and a braking mode is considered a major disadvantage.

Paragraph 18

These and other objects of the invention are achieved with respect to a retarded or electronically braked electric motor configured as a series motor as mentioned at the outset in that the means for switching into braking mode allows for bypassing of the armature and for an external excitation of at least one field winding by means of the supply voltage, when being in braking mode.

Paragraph 21

With respect to the asynchronous motor having a squirrel cage rotor, this object is achieved with an asynchronous motor having at least two, preferably three, field windings, preferably in star connection, by providing means for switching into braking mode allowing a disconnection of at least two field windings from the supply voltage when switching into braking mode, wherein a controllable electronic switch ~~valve~~ is connected between at least two field windings, the controllable electronic switch ~~valve~~ acting as a free wheeling electronic switch ~~valve~~ during braking and being open during operating mode, wherein at least one, preferably two, field windings are externally excited by means of the supply voltage via the ~~a~~ controllable electronic switch ~~valve~~ that is open during operating mode.

Paragraph 24

According to a first development of the invention, a free wheeling electronic switch ~~valve~~ is provided for limiting the voltage across the at least one field winding during braking mode.

Paragraph 27

In this way, ~~it is avoided that~~ the excitation current is prevented from rising ~~rises~~ too high.

Paragraph 28

According to a preferred embodiment of the invention, the series motor is provided with a controllable electronic switch ~~valve~~ for bypassing the armature and being connected across the armature during braking mode.

Paragraph 29

Also for controlling the excitation current through the at least one field winding, a controllable electronic switch ~~valve~~ may be provided.

Paragraph 30

An electronic switch ~~valve~~ in this application shall be regarded in general as a semi-conductor component having a suitable control, such as a triac, a thyristor, a transistor, in particular a field effect transistor, or the like. In the simplest case also a diode merely giving a preferred direction of current may be regarded as an electronic switch ~~valve~~.

Paragraph 31

Herein, in particular an optical coupling device, such as an optical diode in combination with an optical triac, may be provided for driving the valve. Thereby a decoupling is effected between the control circuit and the current circuit to be switched, in which the controllable electronic switch ~~valve~~ is provided.

Paragraph 32

As far as desired also a switch having mechanical contactors or a relay could act as an electronic switch ~~valve~~.

Paragraph 33

According to a further development of the invention, the controllable electronic switch ~~valve~~ connects the at least one field winding via a load resistance to the supply voltage when being in braking mode.

Paragraph 35

According to an improvement of this design, the controllable electronic switch ~~valve~~ connects the at least one field winding via a load resistance and at least one excitation winding to the supply voltage.

Paragraph 44

If the electric motor according to the invention is designed as an asynchronous motor having a squirrel cage rotor, then the controllable electronic switches ~~valves~~ may for instance be designed as triacs that each are in series with a diode.

Paragraph 45

Preferably, herein the valve acting as a free wheeling electronic switch ~~valve~~ is operated at a current flow angle of 180° during braking mode, while the current flow angle of the electronic switch ~~valve~~ for external excitation can be controlled to a value of # 180° during braking mode.

Paragraph 61

Fig. 13 a modification of the embodiment of Fig. 10, having two diodes and only one controllable electronic switch ~~valve~~ for braking control, shown in asymmetric configuration;

Paragraph 63

Fig. 15 an embodiment of an asynchronous motor according to the invention, comprising

three poles and a braking circuitry having controllable electronic switches ~~valves~~.

Paragraph 64

An electric motor according to the invention may be utilized, ~~advantageously~~ for instance, for driving a retarded or electronically braked angle power tool, such as for operating a retarded or electronically braked angle grinder, a saw or the like.

Paragraph 74

The switches S_1, S_2, S_3 shown in Figs. 1 and 2 are shown in Fig. 3 in generalized form as any components that allow to control a current. Herein this may mean a complete disconnection, such as by means of a mechanical switch or a relay, or may mean a complete turning on, or any intermediate value. Therein, possibly a current limitation may be effected by means of a resistance or an inductance. Utilizing a semiconductor having a suitable control, such as a triac, a thyristor, a transistor, in particular a field effect transistor, such a module can be affected ~~effected~~ utilizing electronic means only.

Paragraph 81

The motor 10b comprises an armature 12, which is arranged symmetrically between two field windings 14, 16 in series. While one field winding 14 is directly connected to one pole of the supply voltage 17 at its end opposite the armature 12, the other field winding 16, at its end opposite the armature 12, is connected to the second pole of the supply voltage 17 by means of an electronic switch ~~valve~~ V_1 that is configured as a triac. The electronic switch ~~valve~~ V_1 is driven via a phase current control 18, as generally known in the art. Up to now, this circuitry corresponds to a series motor having field

windings 14, 16, armature and electronic switch ~~triac~~ V_1 with phase current control 18 according to the prior art, shown in operating mode.

Paragraph 82

Now, according to the invention, a braking module designated in total with reference numeral 20 is provided, including two electronic switches ~~valves~~ V_3, V_4 and a load resistance R_1. The electronic switch ~~valve~~ V_3 is connected across the armature 12, the valve being configured in this case as a thyristor which may, for instance, be driven by an optical coupling device (not shown). The electronic switch ~~valve~~ V_3 allows to bypass the armature winding 12 in the manner discussed with respect to Figs. 2 and 3. In addition, the electronic switch ~~valve~~ V_4 is connected between the armature 12 and the field winding 14, the electronic switch ~~valve~~ connecting the field winding 14 from one pole of the supply voltage 17 via a load resistance R_1 to the other pole of the supply voltage 17. The excitation current flows herein during braking mode.

Paragraph 83

Also this electronic switch ~~valve~~ V_4 may, for instance, be configured as a thyristor which may be driven by an optical coupling device (not shown).

Paragraph 84

When switching into the braking mode, firstly the electronic switch ~~valve~~ V_1 is opened and the electronic switches ~~valves~~ V_3, V_4 are switched on. Thus, the armature 12 and the electronic switch ~~valve~~ V_3 are shortened and the field winding 14 is externally excited by means of the supply voltage 17 via the electronic switch ~~valve~~ V_4 and the load resistance R_1. Since both electronic switches ~~valves~~ V_3, V_4 are also connected with

their anodes between armature 12 and field winding 14, the reversal of the current flow direction within the armature is automatically provided when switching into braking mode.

Paragraph 85

While the two electronic switches ~~valves~~ V_1 and V_3 may be on/off switches in the easiest case, the electronic switch ~~valve~~ V_4 is configured as a switching element having a preferred direction, namely at least a mechanical switch or a relay in series with a diode. However, preferably the electronic switch ~~valve~~ V_4 is configured as an electronic component having a preferred direction and being switchable, such as a thyristor. The load resistance R_1 serves to limit the excitation current and may, for instance, be configured as a load resistance of about 150 watts, if the series motor 10b is, for instance, configured as a ~~retarded~~ universal motor having a power of about 1,000 watts.

Paragraph 87

The single difference with respect to the series motor 10b rests in the fact that in the embodiment of Fig. 5, an additional excitation winding L_1 is connected in series with electronic switch ~~valve~~ V_3. By means of this additional excitation winding, in which the armature current flows during braking mode, the braking effect is enhanced. Due to this reason, the excitation current flowing via the field winding 14, the electronic switch ~~valve~~ V_4 and the load resistance R_1 can be reduced during braking mode, thus the load resistance R_1 may be designed with a larger resistance value, so that the power loss acting there-across is reduced.

Paragraph 88

A further modification of this embodiment is shown in Fig. 6 and designated in total with numeral 10d. The single difference with respect to the embodiment of Fig. 5 rests in the fact that instead of an additional excitation winding L_1, now an additional excitation winding L_2 lying in series with the electronic switch ~~valve~~ V_4 and the load resistance R_1 is provided.

Paragraph 92

For controlling the motor current as well as the braking current, an electronic switch ~~valve~~ V_1 is provided being designed as a field effect transistor connected with source and drain to the negative pole of the supply voltage 17 and the armature 12, respectively. The field effect transistor is driven at its gate by means of a pulse duration modulation PWM.

Paragraph 93

Again, in parallel to the armature 12, a controllable electronic switch ~~valve~~ V_3 is connected which may, e.g., be configured as a thyristor being connected with its cathode to drain of the field-effect transistor V_1. To avoid excess voltages, which may arise from the fast switching of electronic switch ~~valve~~ V_1 by means of the pulse duration modulation, between drain of electronic switch ~~valve~~ V_1 and the positive pole of the supply voltage 17, a electronic switch ~~valve~~ V_2 is connected serving as a free wheeling electronic switch ~~valve~~. In the case shown, the electronic switch ~~valve~~ V_2 is simply configured as a diode being connected with its cathode to the positive pole and with its anode to the cathode of electronic switch ~~valve~~ V_3 and the armature 12 and drain of electronic switch ~~valve~~ V_1, respectively.

Paragraph 94

The electronic switch V_2, ~~valve~~ configured as the diode, ~~V_2~~ avoids the built up of excess

voltages which might arise along the path formed by armature 12 and the two field windings 14, 16. During operating mode, the electronic switch ~~valve~~ V_3 is switched off, and the power is controlled by electronic switch ~~valve~~ V_1. When switching into braking mode, initially the electronic switch ~~valve~~ V_1 is switched off and thereafter the electronic switch ~~valve~~ V_3 is switched on with a time lag. Thereafter, the electronic switch ~~valve~~ V_1 is switched on for the duration of the braking phase, e.g., for three seconds, until the motor is idle. Thereafter, V_1 and V_3 are switched off. Then the braking phase ends.

Paragraph 95

In Fig. 8, a modification of the circuitry according to Fig. 7, designed for operation with alternate current, is depicted and designated in total with numeral 10f. The armature 12 is arranged asymmetrically with respect to the two field windings 14, 16 and is connected with one pole of the supply voltage 17. The two field windings 14, 16 lying in series with the armature 12 are connected at one end thereof to a bridge rectifier 21, the other alternate current input of which is connected to the other pole of the supply voltage 17. The electronic switch ~~valve~~ V_1, again configured as a field effect transistor, is driven at its gate by means of a pulse duration modulation PWM and is connected with its drain to the positive pole and with its source to the negative pole of the bridge rectifier 21.

Paragraph 96

For bypassing the armature 12, electronic switch ~~valve~~ V_3 is connected in parallel thereto, while the electronic switch ~~valve~~ V_2, which again serves as free wheeling electronic switch ~~valve~~, is connected in parallel to the two field windings 14, 16. The

electronic switches ~~valves~~ V_2, V_3, which again may be configured as thyristors, are poled in such a way that the two cathodes are connected with each other.

Paragraph 97

Again, during operating mode the two electronic switches ~~valves~~ V_2, V_3 are inactive, so that the braking module 20 is without any effect. Thus, during operating mode the motor 10f is solely controlled by means of V_1 which is driven by means of the pulse duration modulation PWM. When switching into braking mode, initially the electronic switch ~~valve~~ V_1 is switched off. Thereafter, the electronic switches ~~valves~~ V_2, V_3 are switched on with a delay, and V_1 is switched on for the duration of braking, e.g. for 3 seconds, until the motor comes to a rest. Subsequently, V_1, V_2 and V_3 are switched off, this being the end of the braking phase.

Paragraph 100

For limiting the excitation current during braking mode, instead of a load resistance now a controllable electronic switch ~~valve~~ V_5 being configured as a field effect transistor is utilized, being driven at its gate by means of a pulse duration modulation PWM.

Paragraph 101

In the case shown, again a symmetric arrangement of the armature 12 between the two field windings 14, 16 is shown. While the one field winding 14 is connected to one pole of the supply voltage 17, the other field winding 16 is connected at its end opposite the armature 12 to the other pole of the supply voltage 17 by means of an electronic switch ~~valve~~ V_1 configured as a triac. The triac is driven by means of a phase current control 18.

Paragraph 102

For bypassing the armature winding 12 during braking mode, again a controllable electronic switch ~~valve~~ V_3 is provided, while across the field winding 14 a controllable free wheeling electronic switch ~~valve~~ V_2 is connected to limit any voltage surges at the field winding 14. For controlling the excitation current during braking mode, the electronic switch ~~valve~~ V_5 is provided which is configured as a field effect transistor and connected by means of a valve V_4 to the field winding 14 and to the armature 12 and the two electronic switches ~~valves~~ V_2, V_3, respectively. If the pulse duration modulation PWM can be switched off, then the electronic switch ~~valve~~ V_4 merely serves to provide the correct current direction to electronic switch ~~valve~~ V_5. Therefore, it may be a diode in the simplest case. If the pulse duration modulation is not configured for switching off, then the electronic switch ~~valve~~ V_4 is configured as a controllable electronic switch ~~valve~~, as well as the two other electronic switches ~~valves~~ V_2, V_3, for instance as a thyristor. To guarantee a potential separation, again for driving the electronic switches ~~valves~~ V_2, V_3 and possibly V_4, an optical coupling device may be utilized.

Paragraph 103

As can be seen from Fig. 9, the electronic switches ~~valves~~ V_2, V_3, V_4 are each connected with its anode side between the field winding 14 and the armature 12.

Paragraph 104

During operating mode, the electronic switches ~~valves~~ V_2, V_3, V_4, V_5 are switched off, so that the known configuration of a series motor results which is controlled by means of electronic switch V_1, which may comprise a triac, ~~V_1~~ in combination with phase current

control 18. For switching into braking mode, initially V_1 is switched off by means of the phase current control 18, and the electronic switches ~~valves~~ V_2, V_3 are switched on with a certain time delay. Thereafter, the electronic switches ~~valves~~ V_4, V_5 are switched on for the duration of the braking phase, until the motor comes to a rest. Thereafter, the electronic switches ~~valves~~ V_4, V_5 and V_2, V_3 are switched off, whereby the braking phase ends.

Paragraph 105

In Fig. 10, a modification of the series motor of Fig. 9 is shown with asymmetric configuration of the armature 12 and depicted in total with 10h. Apart from the asymmetric configuration, the design and operation of the motor 10h completely corresponds to the design described before with respect to Fig. 9. The armature 12 is connected to one pole of the supply voltage 17 and connected with its other end to the two field windings 14, 16 arranged in series. The end of the field winding 16 opposite the armature 12 is connected to the other pole of the supply voltage 17 by means of the electronic switch ~~valve~~ V_1 being configured as a triac. For control, again a phase current control 18 is provided. For bypassing the armature 12, a controllable electronic switch ~~valve~~ V_3, possibly being configured as a thyristor, is connected in parallel thereto. Across the two field windings 14, 16, the free wheeling electronic switch ~~valve~~ V_2 is connected with its cathode to the cathode of valve V_3 and to the armature 12 and the field winding 14, respectively. For controlling the excitation current through the field windings 14, 16 and the electronic switch ~~valve~~ V_3 during braking mode, again the electronic switch ~~valve~~ V_5, configured as a field effect transistor, is provided and being

driven by means of a pulse duration modulation PWM and being connected between the triac and the field winding 16 by means of a electronic switch ~~valve~~ V_4. As described before, V_4 may be a simple diode, in case the pulse duration modulation PWM is configured for switch-off.

Paragraph 107

The basic configuration of motor 10i is completely identical to the circuitry of the motor 10g according to Fig. 9. Merely the electronic switches ~~valves~~ V_2, V_3, and V_4, which according to Fig. 9 were merely shown schematically, are now depicted in their actual configuration.

Paragraph 108

V_4 is configured as a simple diode, since V_5 can be switched off by means of the pulse duration modulation PWM. The two electronic switches ~~valves~~ V_2, V_3 are each configured as triacs, which each are driven by means of an optical triac.

Paragraph 109

The electronic switch ~~valve~~ V_2 (free wheeling valve) comprises a triac 22 which is connected between the armature 12 and the field winding 14 by means of a diode 24 which is connected with its cathode to the supply voltage 17. For driving the triac 22, an optical triac 28 is provided which is connected to the gate of triac 22 on the one hand and to the connection with the anode of diode 24 via a resistor 26 on the other hand. The optical triac 28 is connected via a resistor 30 to the line 40 which is connected to the anode of electronic switch ~~valve~~ V_4, the armature 12 and the field winding 14. The optical triac 28 is controlled by means of an LED.

Paragraph 110

In a corresponding manner, the electronic switch ~~valve~~ V_3 for bypassing the armature 12 comprises a triac 32 being connected in parallel to armature 12 between the line 40 and the connection to field winding 16. A diode in this circuit is superfluous. Again, the triac 32 is driven by an optical triac 38 which is connected to the gate of triac 32, is coupled to the line 40 via a resistor 36 and is connected via a resistor 34 to the connection of triac 32 to armature 12 and field winding 16. Again, for driving the optical triac, an LED is utilized.

Paragraph 115

Herein, the pulse duration modulation of Fig. 8 was replaced by a phase current control 18. The latter controls the electronic switch ~~valve~~ V_1, now being configured as a triac, during operating mode as well as during braking mode. Naturally, the rectifier 21 is deleted herein. With respect to the reminder, the operation of this configuration completely corresponds to the operation explained before with respect to Fig. 8.

Paragraph 116

During operating mode, electronic switch ~~triac~~ V_1 is typically driven with both half waves. Herein, the phase control angle α is between 90° and 180°. By contrast, during braking mode only the positive half wave is passed, for instance with α of 160°.

Paragraph 119

Herein, the circuitry was simplified with respect to the embodiment of Fig. 10 by providing a electronic switch ~~valve~~ V_6, designed as a triac, connected between the wire connection between armature 12 or field winding 14, respectively, and the electronic switches ~~diodes~~

V_2, V_3, <u>which may be diodes,</u> the <u>electronic switch</u> ~~valve~~ V_6 being driven by the control 42 of <u>electronic switch</u> ~~valve~~ V_5 (PWM). In this case, the <u>electronic switches</u> ~~valves~~ V_2, V_3 may be configured as simple diodes. Apart from this, the operation of this design completely corresponds to the one of Fig. 10.

Paragraph 124

For switching the motor 10m on and off and for switching between operating mode and braking mode, a two-pole on/off switch S_1 having the poles 50 and 52 is provided. For braking the motor 10m, a braking circuit designated in total with 20 is provided. The braking circuit 20 comprises a <u>electronic switch</u> ~~valve~~ V_8 lying in series with a diode 48, and by means of which the two field windings 14, 16 are connected in series between the two phases L_1 and L_3, and thus being externally excited by means of a pulsating direct voltage, when the <u>electronic switch</u> ~~valve~~ V_8 is closed.

Paragraph 125

Simultaneously during braking mode, a <u>electronic switch</u> ~~valve~~ V_7 acting as a free wheeling <u>electronic switch</u> ~~valve~~ is closed across the two field windings 14, 16 via a line 54, the <u>electronic switch</u> ~~valve~~ being in series with a diode 46. By means of the free wheeling <u>electronic switch</u>~~-valve~~ V_7, a further rotation of the motor 10m is avoided during braking mode.

Paragraph 126

As shown, the two <u>electronic switches</u> ~~valves~~ V_7, V_8 may be designed as triacs driven by means of a control 44.

Paragraph 127

During operating mode, both electronic switches ~~valves~~ V_7, V_8 are open and the switch S_1 is closed, so that the known circuit of a 3-phase asynchronous motor in star connection is given. For switching into braking mode, the switch S_1 is opened and both electronic switches ~~valves~~ V_7, V_8 are closed. While the electronic switch ~~valve~~ V_7 is fully opened, i.e. is operated at a phase current angle of 180°, the phase current angle of the electronic switch ~~valve~~ V_8 is, preferably, regulated by means of the control 44 to an intended value between 0° and 180°, to allow a control of the braking.

Paragraph 128

It will be understood that the electronic switches ~~valves~~ V_7, V_8 may also be chosen as valves controllable in any other way, such as transistors, in particular field effect transistors.